Johns Hopkins Scientist Tracks the Rise and Fall of Life

Idaho National Laboratory podcast by Roberta Kwok

Sometimes, even momentous events -- like the beginning of life on another planet or the destruction of life on Earth -- leave only the faintest traces behind. Scientist Luann Becker at Johns Hopkins University has made a career out of searching for those traces and reconstructing what might have happened long ago.

Becker is probably best known for her work investigating the causes of mass extinctions. She's argued that one of those extinctions, called the Great Dying, was triggered by a giant asteroid that slammed into Earth 250 million years ago. Becker has looked for evidence of this collision in old sediment layers around the world. And she's found exotic carbon molecules -- known as buckyballs or fullerenes -- that may have been carried to Earth from outer space.

Becker is also interested in life beyond our planet. She's working on an instrument that will get launched to Mars as part of a European mission in 2013. The instrument, known as a mass spectrometer, will hunt for organic molecules that may have been left behind by long-dead microorganisms. To find these ancient signs of life, the mission will search where no man (or rover) has searched before -- up to 2 meters below the Martian surface.

Becker visited Idaho National Laboratory in early November to give two seminars and explore possible collaborations. I sat down with her to find out more about her work.

Q: Luann, you're working on an instrument called the Mars Organic Molecule Analyzer, also known as MOMA. Can you tell me what exactly this instrument is going to do on Mars?

A: Well, hopefully, it's going to tell us a little something about what the past chemistry on the surface of Mars was like. One of, I think, the most compelling questions you can ask in science is whether life ever evolved beyond the Earth. And the reason we're so fascinated with Mars is because we think that Mars was very similar to the early Earth, and therefore, there's a good reason to think that, perhaps, if there ever was any interesting chemistry that might have led to some kind of life on Mars, then we might actually be able to unravel that. And using an instrument like MOMA is the ideal instrument to use.

Q: What exactly will the instrument do? Can you describe how it's going to work?

A: Sure. What we're trying to do is take samples -- hopefully subsurface samples -- using a drill. We're going to look directly at organic molecules. These are the same molecules that we can look at and detect on the Earth every day. So in a way, we're trying to take a mass spectrometer that you use in your laboratory and make a very miniaturized version of it, kind of like a tricorder. If you remember *Star Trek*, this is really quite true. What we're trying to do is make the first-generation tricorder and go out and actually tell you something about what kinds of organics may be in the atmosphere, what's in the sediments and what may be in the subsurface rocks.

Q: And why is it so important to look below the surface of Mars for signs of life?

A: Well, as we found out in the mid-'70s with the Viking missions, unfortunately, the surface of Mars is a very harsh environment. It's getting constant bombardment from what we call cosmic rays. These things tend to take any organic matter and transform it into something that makes it basically useless to try to evaluate. And so we've learned through the Viking missions that the way to attack this problem is to come equipped to drill or do some subsurface sampling. And in fact, sampling will be critical to our ability to use MOMA effectively.

Q: How is this instrument going to be different from instruments that have been used previously to look for life on Mars?

A: Well, we're actually going to try to step out and do something very different from previous investigations. We're going to take a new approach and add what we call a laser mass spectrometer. Lasers have been used in space but never for the detection of organic compounds, even though they're used routinely in biology labs all over the world. So traditionally, people would use pyrolysis -- heating up the sample and trying to make the sample go into the gas phase, if you will, so that they could then detect it. This time, we're going to use a laser to actually lift off the heavier, more labile organics and try to look and survey what is in that heavy molecular weight range. And if we can use the combination of that with the pyrolysis approach, then we think we're going to get the true nature of what the organics look like on Mars.

Q: I understand that you travelled to Antarctica a few years ago and actually tested this laser technique there. Why did you want to test it in Antarctica?

A: Excellent question. Well, Antarctica's one of the places in the world today that is still rather pristine, hasn't seen a lot of human activity, and it very much mimics the kind of cold, desert-like environment that we know exists on the surface of Mars today. So it's what we call a good Martian analogue. And when you're doing instrumentation development, you want to try to test it in those kinds of environments as much as you can. So it's very cold, it's very dry, and so it gives us an opportunity to take our instrument out there and see how it can behave in the real world.

Q: And are you nervous at all about MOMA getting launched into space?

A: Of course. I mean, I think that anytime you get into this kind of business, you know you're taking risks. But I have to say that the technology that we have developed over the years through NASA and also through the European Space Agency are all very viable. And I think that if you're going to put yourself in anybody's hands, if you put them in the hands of those two agencies, the probability of you being successful is very high. Because after all, even though we've had some failures, we've had much more successes.

Q: Now, you've also done research in a different area: trying to find out the causes of mass extinctions on Earth. I think most people are familiar with the extinction of the dinosaurs, but you are actually working on a different event, which was called the Great Dying. Can you tell me more about that event?

A: Yeah, it's actually not totally unrelated to trying to understand how life evolved on our own planet. That certainly plays a role in how we search for life beyond the Earth. But yes, the Great Dying is the end-Permian extinction event. It occurred much farther back in time than, say, the dinosaur event. So we're going from 65 million years ago to 250 million years ago. So that's a time when the Earth was a very different place. We had a supercontinent, which we referred to as Pangea. And at that time, life was very, very prolific, both in the oceans and on the land. And yet, in a very short period of time, geologically speaking -- maybe 10,000 years or less -- we had almost a complete extinction of all life on the planet. Some 90 percent of all the ocean life was killed. Eighty-five percent of all the life on the continent just disappeared. And it is the greatest extinction event in history on the Earth. So it makes it a very interesting, provocative question to ask: What happened?

Q: Your work suggests that it was similar to the dinosaur extinction -- that, you know, an asteroid or a comet collided with the Earth and caused this mass extinction. How did you come to that conclusion?

A: We basically began to take a look at the best and most well-preserved places in the world -- Australia, South Africa, China -- where we could look at this boundary event. So what we've done is we've taken the same types of clues that led to the discovery of the impact event associated with the dinosaur event to look for a new impact crater called Bedout in the northwestern Australia and have applied the same science techniques to come to the conclusion that this happened.

Q: And as part of this work, you've analyzed these molecules -- these carbon molecules called buckyballs. How does that fit in with this extinction event?

A: Well, fullerenes are the third form of carbon besides diamond and graphite. They are relatively new in terms of us knowing that they actually existed. But these molecules are stardust. They virtually form at conditions that are conducive to what we think happens in big carbon stars. And so, just like anything, they get incorporated into these meteorites and comets and can get carried to other planets like our own. All the lines of evidence -- shocked mineral grains, precious metals you only find in meteorites, and fullerenes -- were found in several locations worldwide for the dinosaur event. We were able to do the same thing with the Permian. And in fact, we used that evidence to then hone in on a place where there might have been a giant impact event 250 million years ago.

Q: And you actually found some interesting elements inside these fullerenes or these buckyballs, right?

A: Yeah, the true key to establishing that the fullerenes we're looking at must have come from some kind of impact event is that they hold inside of their structure -- remember, the fullerene molecule looks like a soccer ball. It actually has a three-dimensional, closed structure all made of carbon. These carbon molecules, when they form around stars, can entrap gases that are being emitted from the stars, and some of those gases are what we call the noble gases, like helium and argon. And so what we've been able to do to establish the nature of how the fullerenes formed was to separate the fullerenes out of these rocks in these event markers and then measuring the ratios of these gases, which can only be explained as being extraterrestrial in their compositions.

Q: What was the reaction of scientists when you published this research?

A: Well, as it always is, when you discover something new and different, you come under a lot of scrutiny. And I think the first, initial sort of reaction was of great surprise. But of course, you know, when you're doing new things and you're trying to make discoveries, you should expect to be challenged. And so we were naturally challenged on how we were actually doing our measurements and whether or not we were really, truly measuring what we thought we were. And in fact, over the course of the last few years, even though we've had debates, lots of new evidence has come to the surface that seems to be very supportive of what we're doing. And so I think we're right in the middle of where we should be in terms of this debate, and time will tell, but I think things have mostly been going our way.

Q: Can you take us back 250 million years ago and describe what this would have looked like? I mean, what would have happened when this asteroid hit the Earth, and what would the impact have been like?

A: Well, if you were close by, you were probably in bad shape. I mean, obviously, an impact event of this size packs a pretty serious punch -- mega-megatons of TNT, causing massive tsunamis and big tidal waves, probably triggering some localized volcanism and certainly emitting a lot of what we call greenhouse gases, which then ultimately, over short periods of time, put pressure on the ecosystem, change the climate, change the environment that was so familiar to those organisms and animals that were living there at that time. Those were the things that caused animals to become extinct. If they can't adapt fast enough, then they're not going to survive. So the initial effect is yes, great devastation, especially close by. But it's the buildup of some of these emissions and other things that are a consequence of the impact event that ultimately cause the extinctions.

Q: Now, it turns out that these extinction events have actually happened several times on Earth. Should we be worried at all? Is a giant asteroid going to wipe out human civilization?

A: Well, that's an interesting question because something that recently became a topic of interest for me -- and you may be hearing about soon in the news -- is the idea that back when human beings first came to North America, there was another great extinction. And it turns out there may have been yet another impact event, maybe a comet in this case. So the answer to your question is: I think you always have to be looking for these objects. We do that all the time. I'm not sure we're ready to do *Armageddon* or something like that, but of course you want to keep track of these types of things. These events are natural occurrences. Hopefully, the time scales that these bigger events happen are going to keep us out of that ultimate disaster.

Q: Now, the two areas of research that we've been talking about -- looking for life on Mars and looking for the causes of mass extinctions -- seem a little different. What's the connection for you?

A: I think the connection really is -- you track how life evolved on our own planet, and you learn a lot about how the planet has changed and what actually influences it. The same thing happens on Mars. You know, Mars -- if you look at Mars today, it doesn't look that unlike the moon. There's mega-impact events that have obviously taken that planet and changed it forever, possibly even prohibited life from ever forming on the planet beyond maybe a microbial stage. So I think that when you do these sorts of searches, even though they may seem like they're very different, there's a lot of commonality in terms of trying to understand what does influence life, what makes it occur, what takes it out.

Q: Luann, thanks so much for talking to me.

A: You're welcome.